Functional Properties of Camelina Protein Concentrate Extracted by Hot Oil-Pressing and Salt Precipitation and the Effect of Hydrolysis on Protein Functionality

Lucy Hansen

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ABSTRACT

There is a continued demand for high protein foods, and plant proteins in particular are trending. Camelina is a sustainable oil seed that is emerging as a new potential protein source, although there is currently not much information available on camelina for food use.

The objectives of this study were to characterize select functional properties of camelina seed after hot oil-pressing and extraction by salt precipitation. A portion of the resulting camelina protein concentrate was enzymatically hydrolyzed in attempt to improve solubility and functional properties. Whey protein isolate and soy protein isolate were also tested for comparison.

SDS-PAGE was performed to characterize subunits within each protein. Solubility was measured at pH 3.4 and 7.0 under heated and non-heated conditions. The emulsification capacity, emulsion stability, gel strength, and water holding capacity were assessed.

The solubility of camelina protein was slightly greater than SPI at pH 3.4 but inferior to WPI. At pH 7.0, the solubility of camelina protein was inferior to both WPI and SPI, which also led to inferior functionality as tests were conducted at pH 7.0. One notable exception was that the water holding capacity of camelina was equivalent to that of SPI with nearly 100% water retention. Hydrolysis at DH 8.6% was found to have a neutral or negative impact on all functional properties of camelina protein.

Further research on camelina protein should be performed, particularly at an acidic pH to determine if its functional properties could be superior to SPI under acidic conditions.

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1. INTRODUCTION

1.1 Objectives

One of the objectives of this project was to evaluate select functional properties of protein extracted from camelina seed through salt precipitation. Another objective was to determine the impact of hydrolysis on the functionality of camelina protein in reference to whey protein isolate and soy protein isolate.

1.2 Importance of protein

Protein is one of the three macronutrients and is essential in maintaining normal functioning of the human body. There are numerous types of protein within the body, including those that constitute muscle, collagen, skin, enzymes, antibodies, and other cellular components (Nestle Health Science). They play a role in crucial reactions and processes constantly occurring within the body, and so there is a daily requirement for protein in the diet. Consumers are generally aware of the importance of protein and the health benefits associated with a high protein diet. Protein continues to gain traction, with 60% of adults seeking to increase their protein intake (Sloan 2018).

1.3 Growing interest in plant protein

High protein foods are a current market trend and the market continues to grow. By 2025, the global market for protein ingredients is expected to reach a value of nearly $50 billion (Grand View Research 2018). Plant proteins are forecast to play an important role in meeting this high demand. By 2022, the market for plant based proteins is expected to be valued at $10.9 billion (Research and Markets 2017).

There are several reasons for the interest in plant proteins. The rising world population heightens the need for new protein sources, and producing plant proteins is a more efficient use of the limited natural resources available than producing animal proteins (Reijnders and Soret 2003; Sabate et al 2015). Additionally, it costs about ten times as much to produce animal protein as it does plant (Wouters et al 2016). There is also a growing trend of vegetarian and vegan diets for ethical, environmental, religious, and cultural reasons among others. Furthermore, many consumers are more conscious about their diets and view plant proteins as healthier than meat (Sloan 2018).

Soy protein is a well-established plant protein because it is grown in many areas of the world and is relatively accessible, inexpensive, and highly functional (Asgar et al 2010). However, soy is one of the eight major allergens (FDA 2018). Other sources of plant proteins are under investigation as non-allergenic, non-GMO alternatives to soy. Legumes, pulses, cereals, and oilseeds such as canola have all been explored as possible protein sources, demonstrating that the market for plant proteins is actively growing (Asgar et al 2010). Therefore, there is an ongoing demand for plant protein sources that camelina protein may have potential to help meet.

1.4 Camelina

Camelina *sativa* is an annual oilseed crop belonging to the Brassicacaeae family. Compared to other crops, it is relatively hardy and able to adapt and grow in a wide variety of environmental conditions (Berti et al 2016). It has a relatively short growing season of 85-100 days and both winter and spring varieties exist, making it suitable for crop rotation (Bansal and Durrett 2016). Camelina also has the ecological benefits of

reducing soil and water erosion, minimizing nitrogen losses, and requiring low input and pesticides (Gesch and Archer 2012; Berti et al 2016). Therefore, camelina may serve as an environmentally friendly and practical option for farmers.

Currently, camelina is mainly used for its oil in applications such as biodiesel production, jet fuel, and cosmetics (Berti et al 2016). Camelina seeds typically consist of about 30-40% oil with a fatty acid composition similar to that of canola oil (Berti et al 2016; Putnam et al 1993). The oil is extracted from the seeds by either a cold- or hot-pressing treatment, resulting in the formation of camelina meal of about 40-45% protein and 10% fiber (Putnam et al 1993). Camelina meal is currently used for animal feed, although its desirable nutritional composition gives it great potential to expand into human consumption. However, there is not much research on camelina protein for food use, thus there is a need to evaluate its functional properties in order to determine suitable food applications.

1.5 Research plan and hypotheses

Camelina seeds grown in Morris, MN underwent a hot oil-pressing treatment, in which the majority of the oil was pressed out of the seeds using a lab Komet CA 59 G screw press at 50 °C. The resulting camelina meal was then then extruded as pellets, milled to 50 mesh, and further defatted using hexane. The defatted camelina meal (DCM) was subjected to a salt extraction to concentrate the protein while removing fiber and gums. The resulting camelina protein concentrate (CPC) was enzymatically hydrolyzed to produce a camelina protein hydrolysate (CPH). These proteins were analyzed along with whey protein isolate (WPI) and soy protein isolate (SPI). WPI is a

gold standard protein used widely in industry, especially in beverage applications, and SPI is an established plant protein, so they were selected to serve as reference proteins. However, both whey and soy are among the most common allergens in the United States, so alternative sources of protein are desired.

The four proteins were profiled using gel electrophoresis under both reducing and non-reducing conditions. Protein solubility was determined at pH 3.4 and 7, under heated and non-heated conditions. Functionality tests performed included emulsification capacity, emulsion stability, gel strength, and water holding capacity. Each test was performed in triplicate and the averaged value is reported here. It was hypothesized that camelina protein would have equivalent or superior functionality over soy protein and that hydrolysis of the camelina protein would help increase functionality properties by improving its solubility in water.

2. MATERIALS AND METHODS

2.1 Milling and defatting

Camelina meal pellets were generously provided by General Mills (Minneapolis, MN). A cyclone sample mill (Udy Corp, Fort Collins, CO) was used to mill the pellets to a size of 50 mesh to reduce particle size and allow for better extraction. The milled camelina sample was defatted using hexane in a 3:1 ratio. After 1 hour of shaking, the mixture was centrifuged at 6000 rpm for 6 minutes to help separate the phases. The hexane layer was discarded. This process was repeated two additional times. The DCM was then left in the hood overnight to allow residual hexane to evaporate.

2.2 Protein extraction by salt precipitation

The protein in DCM was extracted following a method adapted from a canola protein extraction protocol described by Wu and Muir (2008). Dispotassium monohydrogen phosphate and potassium phosphate were used to prepare a potassium phosphate buffer (0.05 M, pH 8, 1 M NaCl). DCM was solubilized in the phosphate buffer in a 1:20 ratio. The solution was stirred at 50 °C for 1 hour and then centrifuged at 9,500 rpm for 20 minutes. This first step “salted in” the proteins so that they were extracted into the buffer. The supernatant was therefore collected and the pellet discarded. Ammonium sulfate was added to the supernatant to reach 85% saturation and the solution was stirred for 3 hours at room temperature. The solution was then centrifuged at 9,500 rpm for 20 minutes. At this point, the proteins had been “salted out” of the solution due to the high salt concentration, so the supernatant was discarded and the pellet was collected. The pellet was redissolved in double deionized water (DDW) in a 1:4 ratio and neutralized using sodium hydroxide.

The solution was dialyzed using SnakeSkin dialysis tubing (3.5K MWCO) in order to remove salts and purify the protein extract. The sample was then lyophilized to remove water without denaturing the protein. The protein content of the lyophilized sample was determined by the Dumas AOAC method based on the combustion of nitrogen (LECO, St. Joseph, MI). The general protein conversion factor of 6.25% was used to calculate % protein from nitrogen.

2.3 pH stat hydrolysis

Enzymatic hydrolysis was performed on a portion of the CPC following the pH-stat method optimized by Walter et al (2016). A 2.5% (w/v) protein solution of CPC was prepared and heated to 40 °C and adjusted to a pH of 6.0. Amano Protease M was the enzyme used for the hydrolysis and was added to achieve a ratio of 0.5 g enzyme per 100 g protein. As the enzyme hydrolyzed the protein, the solution became more acidic due to the freed carboxylic acid groups that were initially linked with amino groups in peptide bonds. Every five minutes, the pH of the solution was brought up to 6.0 using standardized 0.2 N NaOH and the amount titrated in was used to monitor the degree of hydrolysis (DH), calculated using the equation by Adler-Nissens (1986):

$$\%\ DH = \frac{B \times N_B}{MP \times \alpha \times H_{total}}$$

$$B = NaOH\ consumed\ (mL)$$

$$N_B = normality\ of\ base\ used$$

$$MP = mass\ of\ protein\ (g)$$

$$H_{total} = number\ of\ peptide\ bonds\ in\ protein\ (\frac{meq}{g})$$

$$\alpha = degree\ of\ dissociation\ of\ \alpha - NH_2\ equation: \alpha = \frac{1}{1 + 10^{pK-pH}}$$

$$where\ pK = 7.8 + \frac{298 - T}{298 \times T} \times 2400, with\ T\ in\ Kelvin$$

The target DH was below 8%, at which point the flask was removed from the titrator and heated in a water bath at 65 °C for 12 minutes to denature the enzyme so as to prevent further hydrolysis. The camelina protein hydrolysate was then neutralized, lyophilized, and the protein content was determined by the Dumas method.

2.4 SDS-PAGE

Sodium dodecyl polyacrylamide gel electrophoresis (SDS-PAGE) was performed on the samples to gain understanding of the protein profiles, based on the method described by Walter et al (2016). A 0.02% (w/v) protein solution was prepared for each sample and combined in a 1:1 ratio with Laemmli buffer so that injecting 5 μL of solution would contain approximately 5 μg of protein. An additional set of samples was prepared with the addition of β-mercapoethanol (BME) to examine the protein profiles under reducing conditions. All samples were run on a 4-20% Criterion TGX precast polyacrylamide gel along with a broad range molecular weight (MW) marker (Bio-Rad Laboratories #161-0318). The gel was electrophoresed at 200V for 35 minutes. The gel was then stained with Coomassie blue staining solution, rinsed with DDW, and destained. The gel was scanned using the Molecular Imager Gel Dox XR program (Bio-Rad Laboratories).

2.5 Solubility

Protein solubility was determined based on the method described by Wang and Ismail (2012). Samples were run at both pH 3.4 and 7.0. Briefly, 1% (w/v) protein solutions were adjust to pH 3.4 or 7.0 using 1M HCl or NaOH and allowed to stir for two hours. Solutions were either left at room temperature or heated in a water bath at 80 °C for 30 minutes. The heated samples were then centrifuged at 13,000 rpm for 10 minutes. An aliquot (200 μL) of the room temperature solution or the supernatant from the heated sample was inserted into a tin capsule and the protein content was

determined using the Dumas method. Solubility was determined as the protein content of the supernatant divided by the protein content of the room temperature solution:

$$\%\ solubiliy = \frac{protein\ in\ supernatant}{protein\ in\ suspension} \times 100\%$$

2.6 Emulsification capacity

Emulsification capacity (EC) was determined based on the method described by Rickert et al (2004). 1% (w/v) protein solutions were prepared in DDW, adjusted to pH 7.0, and stirred for 2 hours. Protein solutions were blended using a homogenizer (IKA RW 20 Digital, IKA Works Inc., Wilmington, NC) with a 4 blade, 50 mm diameter shaft (IKA R 1342) at 860-870 rpm while corn oil dyed with Sudan Red 7B (4 μg/mL oil) was titrated in at a constant rate of a drop per second. After the emulsion formed, oil continued to be added until the viscosity decreased and the texture became grainy as the emulsion broke. EC was calculated as the g of oil emulsified per g of protein:

$$EC = \frac{volume\ of\ oil\ titrated \times density\ of\ oil}{grams\ of\ protein}$$

2.7 Emulsion stability

Emulsion stability (ES) was determined based on the method described by Rickert et al (2004). 0.1% (w/v) protein solutions were prepared in DDW, adjusted to pH 7.0, and stirred for 2 hours. A 6 mL aliquot of protein solution was added to a beaker and blended with 2 mL of corn oil using a homogenizer (Scilogex D500 homogenizer, Rocky Hill, CT) with a 20 mm shaft spinning at 10,000 rpm. After exactly one minute of blending, 50 μL of the emulsion was vortexed with 5 mL of 0.1% sodium dodecyl sulfate

(SDS). The initial absorbance (A_0) was taken at 500 nm using a spectrophotometer (Beckman 12V-20, Chaska, MN). After 10 minutes, the absorbance was measured again (A_{10}). Using the equation reported by Rickert et al (2004), the ES, in minutes, was calculated as follows:

$$ES = \frac{A_0}{A_0 - A_{10}}$$

2.8 Gel strength

To measure gel strength, 15% protein (w/v) solutions were prepared in DDW, adjusted to pH 7.0, and stirred for 2 hours. An aliquot (1 mL) of each solution was placed into a microcentrifuge tube and heated in a water bath at 95 °C for 10 minutes to induce gelation. The bottom tips of the microcentrifuge tubes were cut off and a light stream of air was used to release the gels from the tubes. The gels were then analyzed using a TA-TX Plus Texture-Analyzer (Stable Micro Systems LTD, Surrey, UK). A 100 mm probe set at a speed of 1 mm/s was used to rupture the gel, and the maximum force required was taken to be the gel strength.

2.9 Water holding capacity

The water holding capacity (WHC) was determined based on a method described by Ochiai-Yanagi et al (1978). Solutions were prepared at 12% protein (w/v) in DDW, adjusted to pH 7.0, and stirred for 2 hours. An aliquot (1 mL) of each solution was transferred to a tared microcentrifuge tube and that weight was recorded as T_1. Samples were heated in a water bath at 95 °C for 10 minutes to induce gelation. Samples were then cooled and water on the cap of the microcentrifuge tubes was wiped

off with a Kimwipe. The tube was then reweighed and recorded as T_2. Samples were then centrifuged for 5 min at 3500 rpm, uncapped and inverted over paper towels for 10 minutes to drain any unbound liquid. The weight of the tube was then recorded as T_3. The percentage of water entrapped by the gel was considered the WHC of the protein and was calculated as follows:

$$\%\, WHC = \frac{T_3 - T_1}{T_2 - T_1} \times 100\%$$

$$T_1 = weight\ of\ protein\ solution\ before\ gelation$$

$$T_2 = weight\ of\ protein\ solution\ and\ microcentifuge\ tube\ after\ gelation$$

$$T_3 = weight\ of\ protein\ solution\ and\ microcentifuge\ tube\ after\ draining\ excess\ water$$

3. RESULTS AND DISCUSSION

3.1 Degree of hydrolysis

Amano Protease M was selected for the hydrolysis as it is supposed to result in hydrophilic peptides that can aid in improving solubility (Amano Enzyme 2015). Plant proteins are poorly soluble, so hydrolysis is often done to reduce molecular weight and increase surface charge of the proteins to help improve solubility and functional properties (Wouters et al 2016). However, extensive hydrolysis may result in peptides that are too small to be functional and may taste bitter. Therefore, degree of hydrolysis should be limited.

The conditions for pH stat were selected to target a degree of hydrolysis (DH) of 8%. The actual DH reached was 8.6%. Hydrolysis was expected to improve the solubility of the camelina protein. The cleaving of peptide bonds frees carbonyl and

amino groups, both of which are ionizable and can increase the charge load of the protein. At pH 3.4, the carboxyl groups are undissociated while the amino groups are protonated, causing the protein to have higher net positive charge overall, while at a neutral pH, carboxyl groups are dissociated and amino groups are mostly protonated (Wouters et al 2016).

3.2 SDS-PAGE

SDS-PAGE separates protein bands within the sample based on size. The SDS breaks noncovalent bonds and imparts a negative charge on all the proteins so that they migrate down the gel when an electric current is applied. The lower molecular weight proteins move further down the gel, while the larger proteins remain closer to the starting point. By examining the gel in Figure 1, it can be seen that both the WPI and especially the SPI constituted larger molecular weight proteins than the camelina samples. The high MW proteins of SPI are often blamed for its limited solubility, although they may also have the positive effects of aiding in gel formation and emulsification properties.

BME is a reducing agent that breaks disulfide bonds within the protein. This Is especially useful if the protein has extensive quaternary structure, as it allows for visualization of subunits within the protein that were previously linked by disulfide bonds. By comparing the camelina samples in lanes 4 and 5 with the corresponding samples under reduced condition in lanes 8 and 9, it can be concluded that the camelina proteins contained some disulfide bonds due to the further migration of the protein bands under the reducing conditions (Figure 1).

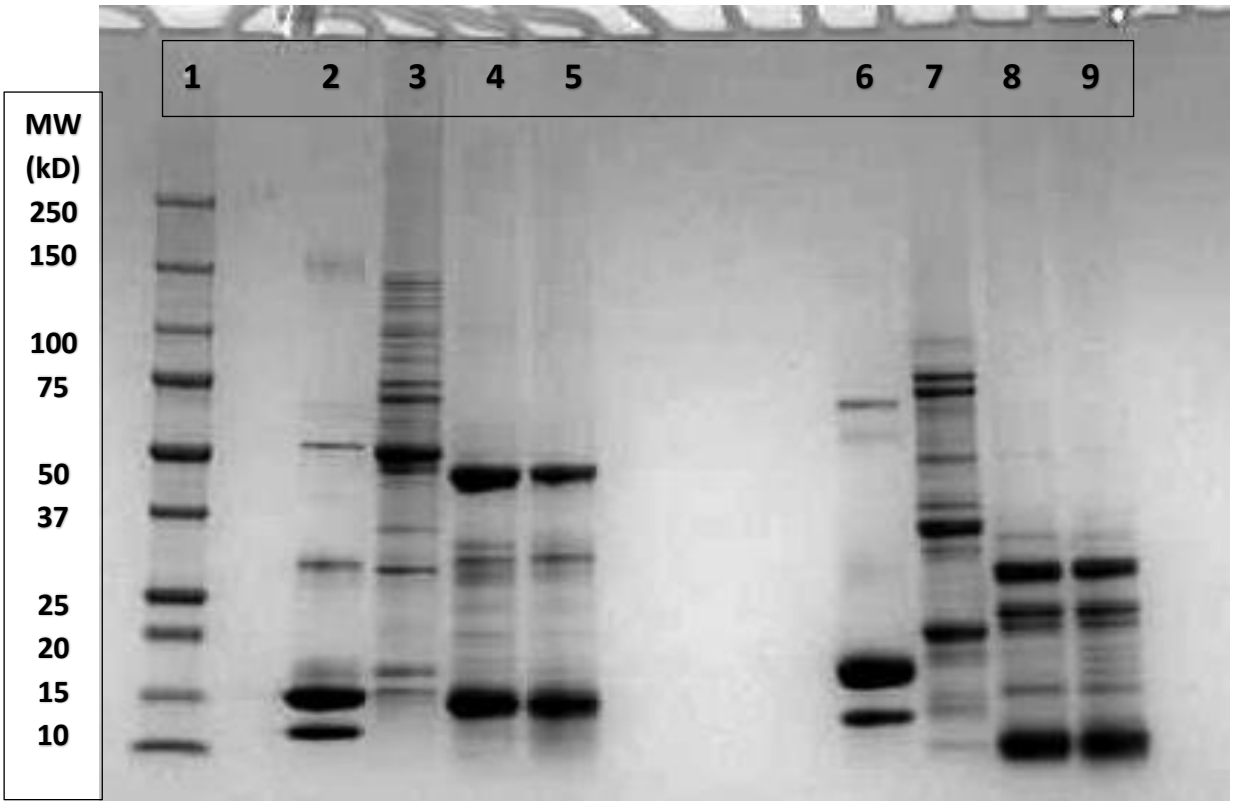

Figure 1: Protein profiling performed by SDS-PAGE under non-reducing (lanes 2-5) and reducing (lanes 6-9) conditions. Lane 1 is the molecular weight marker. Lanes 2 and 6 are WPI. Lanes 3 and 7 are SPI. Lanes 4 and 8 are camelina protein concentrate. Lanes 5 and 9 are camelina protein hydrolysate.

3.3 Solubility

Solubility is arguably the most important characteristic of a protein because many functional properties require the protein to be soluble in aqueous medium (Wouters et al 2016). The solubility of the samples was analyzed based on the amount of protein that stayed in solution after centrifugation versus the original amount of protein put into suspension. Solubility is commonly measured at both a neutral pH as well as pH 3.4 because protein enriched beverages are either acidic or neutral, and so it is important to know the solubility characteristics of a protein at these two pH conditions to determine if it could be used for high protein beverage applications. Additionally, it is useful to

compare solubility under both heated and nonheated conditions. In general, heating can cause denaturation and aggregation of a protein, thus decreasing its solubility. This may be what caused the noticeable drop in solubility of the camelina protein concentrate at pH 7.0 (Figure 2). At pH 3.4, however, camelina protein carries a higher charge load, so it did not experience the same decrease in solubility after heating (Ismail 2018). It is suspected that the smaller MW of the peptides in the camelina protein hydrolysate helped it to maintain solubility at pH 7.0 even after heating.

Past research has shown that enzymatic hydrolysis helps improve solubility because it reduces the MW of the proteins and increases the number of ionizable groups (Wouters et al 2016). However, there was no obvious improvement in solubility of the camelina protein hydrolysate compared to the camelina protein concentrate at either pH. In this case, the unique composition of amino acids and distribution of charges that exist in camelina protein and are largely responsible for its solubility were not improved by limited hydrolysis (Ismail 2018).

WPI is unique in that it has good solubility over the pH range of 2 to 9, whereas in many proteins such as SPI, hydrophobic forces dominate as surface charge decreases and solubility therefore decreases near its isoelectric point (Burrington 2012). This would explain why SPI decreased in solubility at pH 3.4 versus pH 7, while the WPI remained consistently soluble (Figures 2 and 3). The high solubility of WPI may be also be aided in the fact that it has a smaller molecular mass than most plant proteins such as soy and it is naturally highly hydrophilic on the surface (Lam et al 2017).

Unlike SPI which decreased in solubility at pH 3.4 (Figure 3) versus pH 7.0 (Figure 2), the solubility of the camelina protein concentrate and hydrolysate actually

increased under acidic conditions. In fact, at pH 3.4 CPC and CPH had comparable or higher solubility than SPI (Figure 3). This indicates that camelina protein has potential to replace SPI in acidic high protein beverage applications.

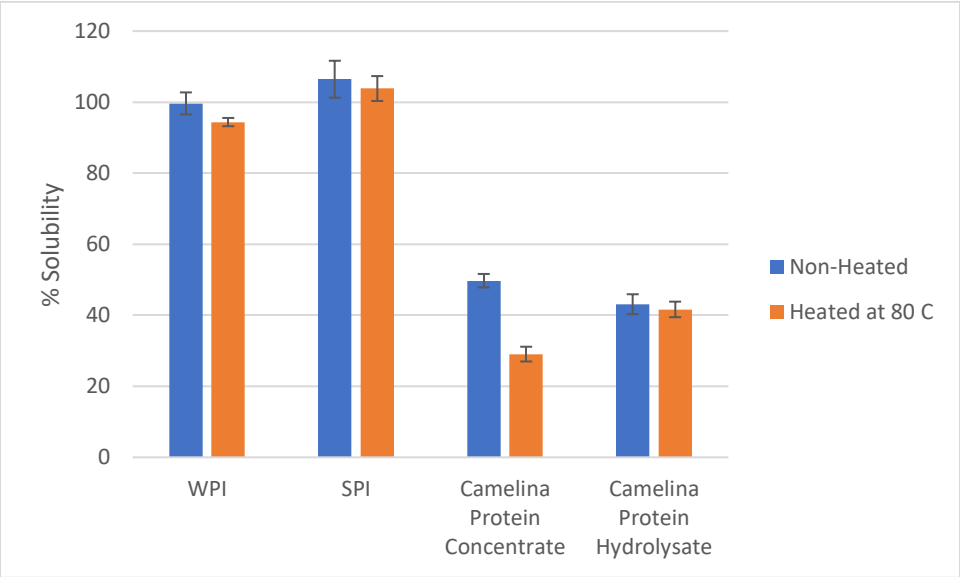

Figure 2: Solubility at pH 7.0 of heated and nonheated protein samples. Bars represent standard errors (n=3).

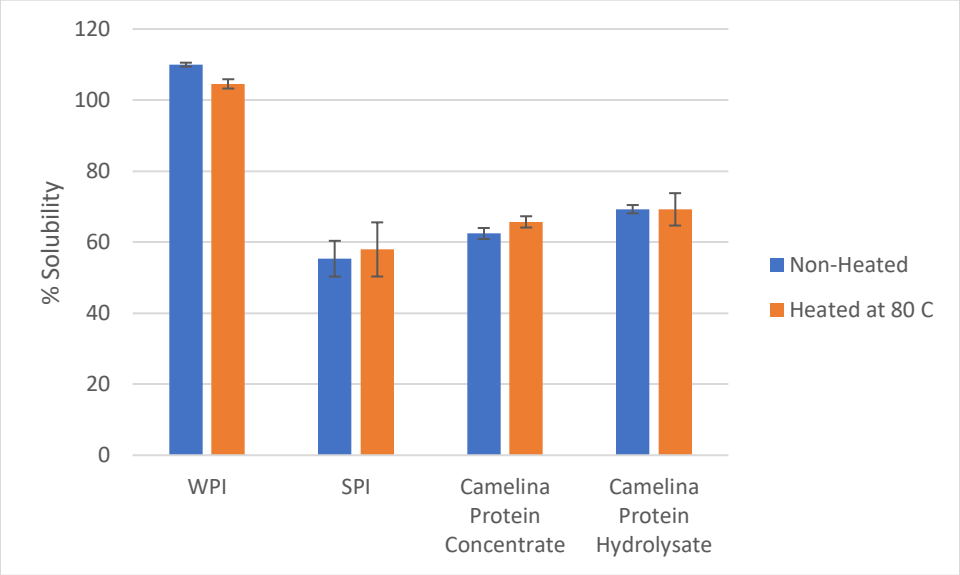

Figure 3: Solubility at pH 3.4 of heated and nonheated protein samples. Bars represent standard errors (n=3).

3.4 Emulsification capacity

Oil is hydrophobic while water is hydrophilic, so a balance of hydrophobic and hydrophilic portions within a protein is needed in order to interact with both phases and form a good emulsion. At neutral conditions, whey protein is known to be a good emulsifier because its structure consists of both charged and uncharged patches of amino acid residues. Plant proteins tend to have higher molecular weights and are less flexible than animal proteins, so their migration to the interface is hindered and their EC is typically lower (Lam et al 2017).

CPC had an EC comparable to SPI, indicating that it may be useful as a substitute to soy in certain food applications. For example, soy is commonly used to produce dairy-free yogurts, ice creams, and cheeses. However, soy is also a major allergen (FDA 2018), so replacing it with camelina protein may be a way to eliminate major allergens while maintaining the integrity of the food.

CPH formed a very weak emulsion and broke almost instantly. Low degrees of hydrolysis can help improve emulsification properties by enabling proteins to migrate and adsorb at the interface more efficiently due to the reduced molecular weight and increased exposure of hydrophobic groups (Lam et al 2017). However, it is speculated that a DH of 8.6% created peptide chains that were too small to act as effective emulsifiers.

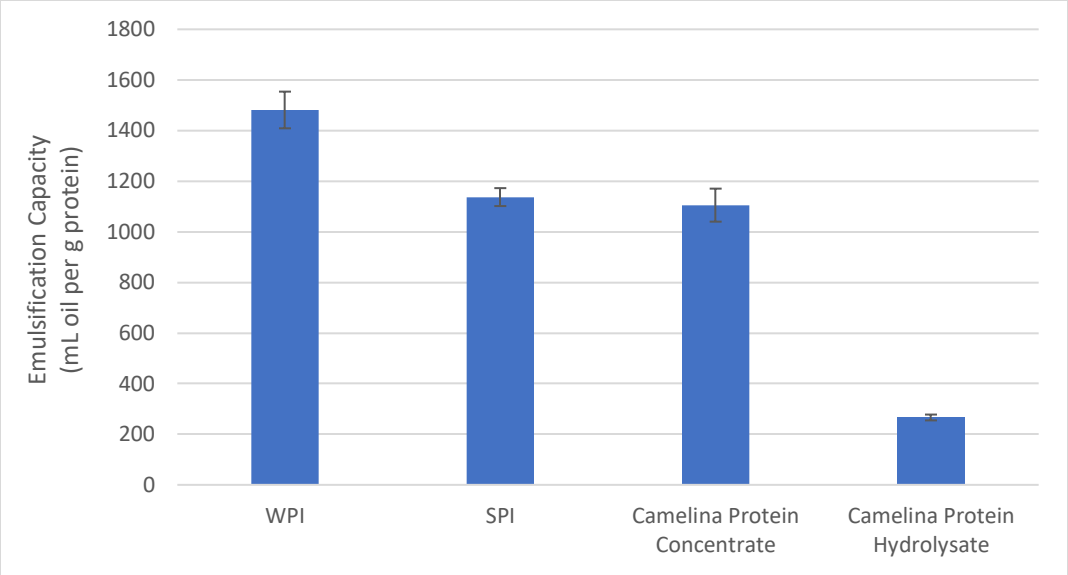

Figure 4: Emulsification capacity of 1% (w/v) protein solutions prepared at pH 7.0. Bars represent standard errors (n=3).

3.5 Emulsion stability

Emulsion stability measures how long a formed emulsion will remain stable before coalescing of oil droplets occurs, based on measuring changes in absorbance of the emulsion over time. WPI and SPI had similar durations of stability, whereas the camelina concentrate and hydrolysate both were relatively unstable. These differences in ES may have been due to the lower solubility of camelina at neutral pH previously reported (Figure 2). It is possible that the lower solubility of the camelina proteins allowed for more protein-protein interactions to occur, thus limiting its interaction with oil in favor of interacting with adjacent protein molecules. Additionally, as shown by SDS-PAGE (Figure 1), WPI and SPI both contained a greater number of large molecular weight proteins, which can help provide stability to an emulsion by forming a thicker film around oil droplets that prevents coalescence (Smith 2017). The films formed by camelina proteins were likely weaker and may have had less electrostatic repulsion

among the proteins on the surface of the oil droplets than those of SPI and WPI, allowing for quicker coalescence of the oil droplets.

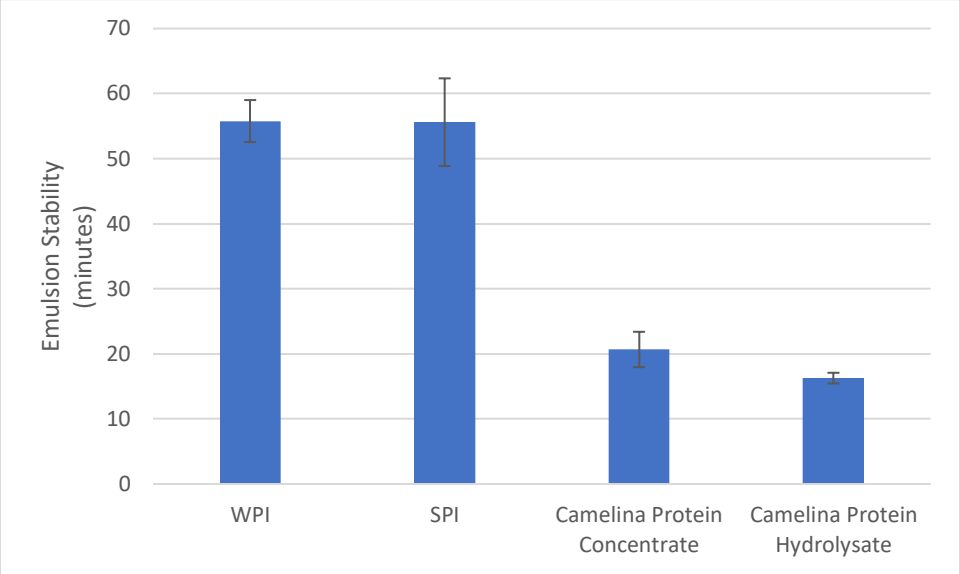

Figure 5: Emulsion stability of 0.1% (w/v) protein solutions prepared at pH 7.0. Bars represent standard errors (n=3).

3.6 Gel strength

Gelation requires a balance of both protein-protein and protein-water interactions. Hydrophobic portions of the protein cause it to associate with other molecules and form junction zones, whereas hydrophilic regions of proteins repel each other and interact with water. The network of protein formed and the water entrapped within is what constitutes a gel.

WPI forms a firm gel because it forms strong interactions amongst molecules via hydrophobic interactions and disulfide linkages, as well has being large in size (Ismail 2018). SPI also has large MW proteins that allow for extensive cross-linking of proteins that contributes to its gel strength. CPC formed a relatively weak gel, and the gel formed

by CPH was even weaker (Figure 6). The hydrolyzed protein chains were likely too short to interact and form a good network, causing the gel to rupture at the slightest disturbance. CPC, having slightly larger proteins, was able to resist a higher amount of force, but it still paled in comparison to the SPI and WPI due to its relatively low molecular weight.

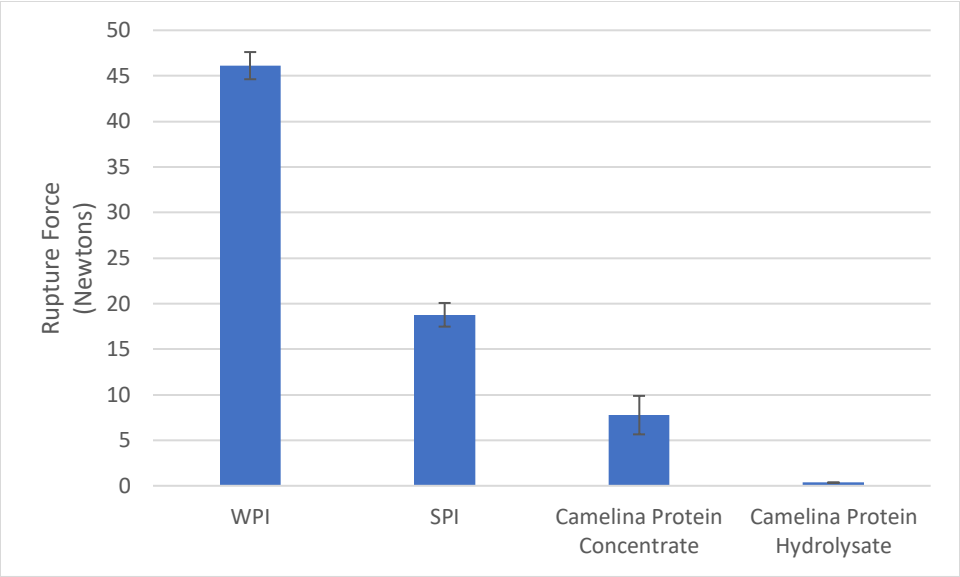

Figure 6: Force (in Newtons) required to rupture a gel prepared at 15% (w/v) protein and pH 7.0. Bars represent standard errors (n=3).

3.7 Water holding capacity

All proteins were prepared at a concentration of 12% (w/v) protein. At this concentration, WPI formed gels within the microcentrifuge tubes but they became liquidy after centrifugation and spilled out when the tubes were inverted, so no results were obtained for WPI. In the future, it is advised that gels be prepared at 15% (w/v) protein as was done for gel strength, as this concentration is known to form firm gels for all protein samples tested.

Of the proteins that formed a gel, they all had water retention over 99% (Figure 7). WHC is especially important to consider for foods that are desired to have a juicy texture. For example, soy protein is commonly used as a meat extender in sausages and burgers because it has a high capacity for retaining moisture during cooking (FAO 2010). Camelina protein, therefore, may be suitable for similar applications.

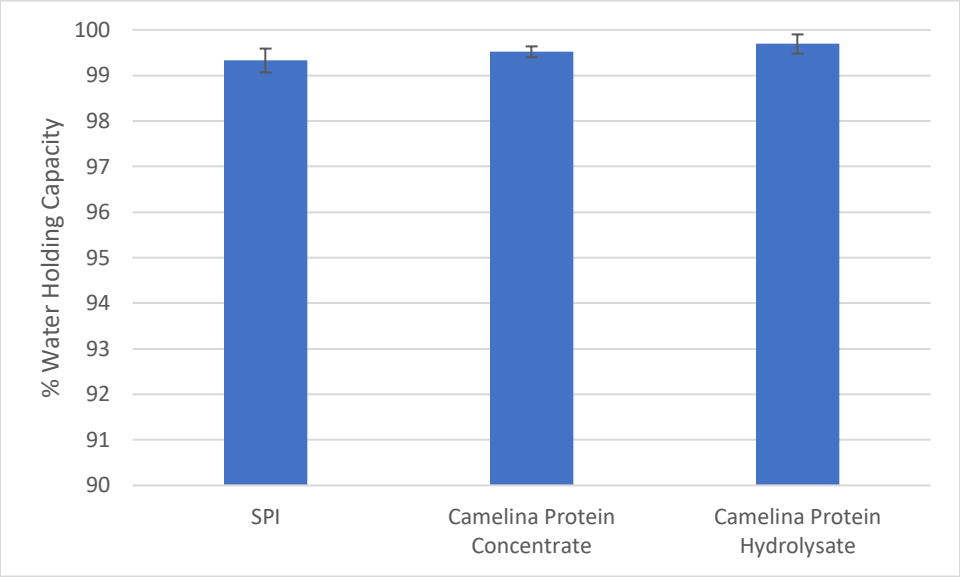

Figure 7: Water holding capacity of gels prepared at 12% (w/v) protein and pH 7.0. Bars represent standard errors (n=3).

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 How camelina compares to whey and soy as a protein source

WPI and SPI both had superior solubility to the camelina protein concentrate and hydrolysate at pH 7.0. Solubility is a major factor in the functionality tests evaluated here, so it is not surprising that WPI and SPI were superior in many of the functional properties as tests were conducted at neutral conditions. However, there were two

notable exceptions. First, at pH 3.4, camelina protein was slightly more soluble than SPI, so camelina may be more suitable for high protein plant-based acidic beverages than soy. Secondly, the water holding capacities of the camelina concentrate and hydrolysate were parallel to that of SPI, so camelina protein may be useful in food applications where water retention is the main concern.

4.2 Implications and recommendations

Further research should be performed on camelina protein to determine its potential as a plant protein. Because the hydrolysate prepared at DH 8.6% had neutral or negative impact on all functional properties, a camelina protein hydrolysate at a lower DH should be evaluated to determine if it could aid in solubility while maintaining or improving functional characteristics. As the solubility of camelina protein appeared to be superior at pH 3.4 versus 7.0, functional characteristics should be tested at pH 3.4 to determine if camelina may have use in acidic food matrices.

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